SPACE FLIGHT APPLICATIONS OF OPTICAL FIBER; 30 YEARS OF SPACE FLIGHT SUCCESS

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Introduction

For over thirty years NASA has had success with space flight missions that utilize optical fiber component technology. One of the early environmental characterization experiments that included optical fiber was launched as the Long Duration Exposure Facility in 1978. Since then, multiple missions have launched with optical fiber components that functioned as expected, without failure throughout the mission life.

NASA Space Flight Communications Links

In 1989, the Cosmic Background Explorer (COBE) satellite included several photonic and optical fiber components. The system functioned accurately enough for the Principal Investigators, John C. Mather of Goddard Space Flight Center (GSFC) and George F. Smoot of Lawrence Berkeley National Labs, to become Nobel Prize in Physics laureates in 2006. Over the next decade, several NASA missions had base-lined optical fiber communication systems, including the International Space Station. In 1992, the Small Explorers Program (SMEX) at NASA Goddard Space Flight Center broke new ground by proving that optical fiber was a viable option for space flight. The SAMPEX, Solar Anomalous and Magnetospheric Particle Explorer, was the first mission out of the SMEX program; it launched in 1992. It was designed for a 1 year mission duration. Sixteen years later it was still functional for science data, and it utilizes the first GSFC-flown optical fiber MIL-STD-1773 communications system as the critical link between the science instruments and the space craft. In addition to those missions mentioned, the following is a summary table that was presented in 1999 at Marshall Space Flight Center as an update after the publication in reference 1 was already released. The information in Table one was updated here to include the actual launch dates from the information reported in 1999.

Table 1: Missions using optical fiber transmission for critical command and handling.

Project Name	Acronym	Launch Date	Technology	Wavelength
Solar Magnetospheric Particle Explorer	SAMPEX	July 1992	MIL-STD-1773,1 Mbps	850 nm
Microelectronic and Photonic Test Bed	MPTB	Dec. 1997	AS1773, 20 Mbps	1300 nm
Microwave Anisotropy Probe	MAP	June 2001	AS1773, 20 Mbps	1300 nm
X-ray Timing Explorer	XTE	Dec. 1995	MIL-STD-1773,1 Mbps	850 nm
Hubble Space Telescope, upgrades	HST	Feb. 1997	MIL-STD-1773,1 Mbps	850 nm
Photonic Space Experiment	PSE	proprietary	MIL-STD-1773,1 Mbps	850 nm
Tropical Rainforest Measuring Mission	TRMM	Nov. 1997	MIL-STD-1773,1 Mbps	850 nm

Over the decade to follow, more varied applications of optical fibers were implemented at NASA GSFC for science instrumentation. In addition to what is listed above, the International Space Station managed by Johnson Space Center used a Boeing-designed optical fiber data bus called the High Rate Data Link (HRDL). The HRDL was configured with 1300 nm graded index multimode optical fiber links and an enhanced MIL-STD-38999 connector with MIL-T-29504 termini. The MIL-STD-1773 optical fiber links typically used the MIL-STD-38999 and MIL-T-29504 termini, where in other cases the customized 140 micron Johanson FC type connector was used. Both cables that were utilized for these communications missions, Brand Rex OC1008 (GSFC) or the International Space Station's version of the Brand Rex

OC1416 are now obsolete as the fiber optic industry boomed into production of fiber-to-the-home-hardware. More experiments and hardware are being added to the International Space Station and must be integrated to the existing HRDL. The Express Logistics Carrier was a large GSFC endeavor to provide a smart warehouse on ISS for a variety of experiments that the general space flight community will supply. Due to the obsolescence of the past ISS technology the latest HRDL interface transceivers have been supplied by Space Photonics, Inc. In the mid 90's an earlier version of SPI supplied the Space Bourne Parallel Fiber Optic Databus (SFODB) transceivers that GSFC had qualified for Earth Orbiter-1, but never flew due to budget cuts.

NASA Exploration and Science Instrumentation

A variety of instrumentation has been built and flown exploiting the advances that optical fiber components have experienced over the last twenty years. In the mid 1990's Lockheed-Martin, while searching for a space flight single mode connector, presented qualification data on the Switzerland Diamond innovation – the AVIM connector. For most space flight instrumentation that requires high performance, the AVIM has been used in single-mode, multi-mode and array configurations. Together with W.L. Gore's FLEXLITE cable, challenging mission requirements could be met. Below is a summary of the missions that used this combination in flight. The altimeters listed use either 532 nm or 1064 nm or both, multimode and or/singlemode fibers. In all cases no flight data was lost due to any anomalies caused by the optical fiber technology. In the case of LRO, both instruments required multi-fiber arrays never before configured in an AVIM and never before used for flight.

Table 2: Missions using optical fiber transmission for receiver optics and signal processing.

Project Name	Acronym	Launch Date	Technology
Geoscience Laser Altimeter	GLAS	Jan 2003	SM & MM – 1064/532 nm; AVIM - FLEXLITE
Mercury Laser Altimeter	MLA	Aug 2004	MM 1064 nm; AVIM - FLEXLITE
Shuttle-Return-to-Flight	Shuttle-RTF	July 2004	SM & MM – NEPTEC camera w/ AVIM – Custom
Lunar Orbiter Laser Altimeter / Laser Ranging on LRO	LOLA on the Lunar Recon Orbiter	June 2009	5 & 7 arrays, 1064/532 nm w/ AVIM enlargement - Custom
Mars Science Lab ChemCam.	MSL	TBD	Broad spectrum – AVIM

Conclusion

All the NASA missions using optical fiber as a transmission link have never reported on-board failures related to the technology. Even when during integration of the US Lab, when a decision was made to launch with known defects and cracks in the fiber, ten years later there are no reported impacts to the ISS operations. NASA has enjoyed over 32 years of space flight success using optical fiber technology.

References

[1] K A. LaBel, C. J. Marshall, P. W. Marshall, P. J. Luers, R. A. Reed, M. N. Ott, C. M. Seidleck, D. J. Andrucyk, "On the Suitability of Fiber Optic Data Links in Space Radiation Environment: A Historical Scaling Technology Perspective," IEEE Aerospace Conference, Volume: 4 , 1998, Page(s): 421-434.

[2] M. N. Ott, "Applications of optical fiber assemblies in harsh environments: The journey past, present and future," SPIE Optics & Photonics Conference, Vol. 7070, August 2009. http://photonics.gsfc.nasa.gov